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Rana khare (Kiyasetuo & Khare, 1986): present distribution, redescription of holotype and morphology of adults and tadpoles

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The holotype of *Rana khare* is redescribed. Tadpole and adult female specimens are described with standard methodology and measurements are given. The external morphology and buccal structures of tadpoles are described. The presence of lateral dermal flap is a secondary male character as it is absent in females. Comparison of adult morphology with other ranine groups shows *Pterorana* to be a member of the genus *Rana* sensu DUBOIS (1992), close to *Sylvirana* but with generalized larval characters which do not allow precise allocation. Presence of dermal flap in other ranid frogs and function of these structures are discussed.

INTRODUCTION

In 1986, KIYASETUO & KHARE described a new frog from Nagaland, north-east India, and erected for it a particular genus, *Pterorana*, because of the presence of well-developed dermal flaps on sides of body and on thighs. DUBOIS (1992) considered this genus to be a subgenus of *Rana*. FROST et al. (2006) did not study *Pterorana* but considered it as a valid genus. As only male specimens have been collected from various parts of north-east India, the female and tadpole morphology remained unknown.

We here give for the first time details on distribution, redescription of holotype, morphology of male and female adults and of tadpole, and data on reproduction of this poorly known species.

MATERIAL AND METHOD

ABBREVIATIONS

Collections

KSC. – Kohima Science College Museum, Kohima, Nagaland, India.
ZSI. – Zoological Survey of India, Kolkota, West Bengal, India

Measurements

SVL, snout-vent length.

Head HW, head width HL, head length, from back of mandible to tip of snout MN, distance from back of mandible to nostril MFE, distance from back of mandible to front of eye. MBE, distance from back of mandible to back of eye. IFE, distance between front of eyes. IBE, distance between back of eyes. IN, inter-narial distance. EN, distance from front of eye to he nostril EL, eye length NS, distance from nostril to tip of snout SL, distance from front of eye to tip of snout TYD, greatest tympanum diameter TYE, distance from tympanum to back of eye. IUE, minimum distance between upper eyelids. UEW, maximum width of inter upper eyelid

Forelimbs HAL, hand length, from base of outer palmar tubercle to tip of toe. FLL, forelimb length, from elbow to base of outer tubercle. TFL, third finger length, from base of first subarticular tubercle. fd1 to 4, finger dilatation width for fingers I to IV fw1 to 4, finger width for fingers I to IV HGL, humeral gland length

Hindlimbs FL, femur length, from vent to knee. TL, tibia length FOL, foot length, from base of inner metatarsal tubercle to tip of toe FTL, fourth toe length, from base of first subarticular tubercle td1 to 5, toe dilatation width for toes I to V tw1 to 5, toe width for toes I to V. IMT, length of inner metatarsal tubercle. ITL, inner toe length.

Webbing MTTF, distance from distal edge of metatarsal tubercle to maximum incurvation of web between third and fourth toe TFTF, distance from maximum incurvation of web between third and fourth toe to tip of fourth toe MTFF, distance from distal edge of metatarsal tubercle to maximum incurvation of web between fourth and fifth toe. FFTF, distance from maximum incurvation of web between fourth and fifth toe to tip of fourth toe. WTF, webbing between third and fourth toe (from base of first subarticular tubercle) WFF, webbing between fourth and fifth toe (from base of first subarticular tubercle) WI, webbing between third and fourth toe when folded along fourth toe (from base of first subarticular tubercle) WII, webbing between fouth and fifth toe when folded along fourth toe (from base of first subarticular tubercle)

SPECIMENS STUDIED

KSC 100-102 (adult ♂) and KSC 115 (adult ♀), Jokhoma river (26°06'N, 92°02'E; alt 1600 m); KSC 103-105 (adult ♂) and KSC 116-117 (adult ♀), Rokhroma stream (26°25'N, 94°07'E; alt 1440 m), KSC 106-108 (adult ♂) and KSC 118-119 (adult ♀), Tsureng stream (26°05'N, 94°05'E, alt. 1050 m); KSC 109-112 (adult ♂) and KSC 113-114 (adult ♀), Japu stream (26°04'N, 94°05'E, alt 1080 m); KSC 051-072, tadpoles from Japu and Tsureng streams.

METHODOLOGY

Amplecting pairs were collected in the field and eggs obtained in the laboratory for further study of development Adult males and females were preserved in 8 commercial formaldehyde solution and tadpoles were preserved in 10 % commercial formaldehyde solution. A series of 25 tadpoles at stage 38 (Gosner, 1960) was used for description. Holotype and paratype were described by A. O. in ZSI in Kolkota using standard methods. Morphological terminology of tadpole follows Altig & McDiarmid (1999), keratodont row formula (KRF) follows Dubois (1995) and developmental stages were determined according to Gosner (1960). Terminology of bucco-pharyngeal features of tadpoles follows Wassersug (1976), preparation for SEM examination comprised dehydration (ethanol), critical-point-drying (liquid carbon dioxide) and gold sputter surface coating. Tadpole and adult measurements were taken with a dial vernier caliper according to the methodologies of Grosjean (2006), Ohler (1996) and Ohler et al. (2002), respectively.

Mean, standard deviation, minimum and maximum were obtained for all variables on a personal computer using SPSS program. Non-parametric statistics (Mann-Whitney *U* test) were applied to compare males and females.

Results

Distributional record

Two adult males of this species were first collected from Sanuoru and Rukhroma waterfalls (26°25'N, 94°07'E, alt. 1400-1440 m) in Kohima district of Nagaland, India and described by Kiyasetuo & Khare (1986) respectively as the holotype (ZSI A.9095) and paratype (ZSI A.9097) of a new species (Chanda et al., 2000). Since the original description of the species in 1986, male specimens have been reported from various parts of north-east India: Arunachal Pradesh (Chanda, 1994, Power & Birand, 2001), Nagaland (Ao et al., 2003); bank of river Tiwang, Sairang (23°36'N, 93°00'E; alt. 2000-2500 m), 21 km from Aizawl, Mizoram (Dey & Ramanujam, 2003), and Dhaleswari river, Bairabi, Mizoram (Sen & Mathew, 2003). Ao et al. (2003) gave the range extension in Nagaland as Rukhroma (alt. 1440 m) and Jokhoma (alt. 1600 m). During the present survey, amplecting pairs were recorded from Jokhoma river (alt. 1600 m), Rokhroma stream (alt. 1440 m), Tsureng stream (alt. 1050 m) and Japu stream (alt. 1080 m).

Description of holotype

ZSI A 9095, adult ♂ (fig. 1): Sanuoru River, Kohima, Nagaland, India.

Size and general aspect. (1) Specimen of moderate size (SVL 50.5 mm), body moderately robust.

Head. (2) Head moderate, longer (HL 19.1 mm) than wide (HW 17.9 mm; MN 15.9 mm; MFE 11.5 mm, MBE 6.2 mm), flat. (3) Snout rounded, slightly protruding, its length (SL 8.35 mm) longer than horizontal diameter of eye (EL 5.65 mm). (4) Canthus rostralis rounded, loreal region concave; rectangular in cross section. (5) Interorbital space

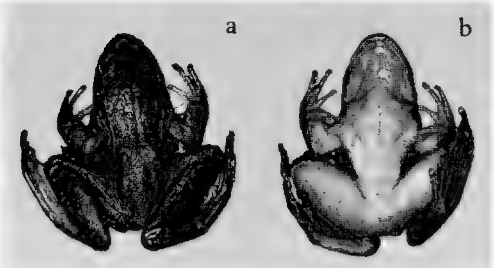

Fig. 1. Holotype of *Pterorana khare* Kiyasetuo & Khare, 1986, ZSI A9095, adult male, SVL 50.5 mm: (a) dorsal view; (b) ventral view.

flat, less broad (IUE 4.53 mm) than upper eyelid (UEW 5.09 mm) and than internarial distance (IN 5.81 mm), distance between front of eyes (IFE 9.7 mm) about three fourth of distance between back of eyes (IBE 13.6 mm). (6) Nostrils oval, with small flap of skin laterally, closer to eye (EN 3.66 mm) than to tip of snout (NS 4.30 mm). (7) Pupil not observable (in preservative). (8) Tympanum (TYD 2.78 mm) distinct, oval, oblique, less than half eye length, tympanum-eye distance (TYE 2.63 mm) about its diameter. (9) Pineal ocellus absent. (10) Vomerine ridge present, without teeth; ridge between choanae, with an angle of 45° relative to body axis, less close to choanae than from each other, as long as distance between them. (11) Tongue small, spatulate, emarginate; median lingual process absent. Tooth-like projection on maxilla absent. (12) Supratympanic fold absent.

Forelimbs – (13) Arm short, fore-arm (FLL 12.0 mm), shorter than hand (HAL 14.4 mm), enlarged. (14) Fingers I and II short, thin, fingers III and IV long, thin (TFL 8.03 mm). (15) Relative length, shortest to longest: II < I < IV < III. (16) Tips of fingers I to IV pointed, enlarged, with latero-ventral grooves, scarcely wide (fd1 1.40 mm, fw1 1.20 mm; fd2 1.40 mm, fw2 0.93 mm, fd3 1.55 mm, fw3 0.93 mm, fd4 1.44 mm, fw4 1.05 mm). (17) Finger II with dermal fringe, webbing absent. (18) Subarticular tubercles distinct, rounded, single, all present. (19) Prepollex oval distinct, two, oval, flat palmar tubercles, supernumerary tubercles on base of fingers I to IV, distinct.

Hindlimbs – (20) Shanks four times longer (TL 30.3 mm) than wide (TW 7.7 mm), longer than thigh (FL 27.4 mm) and distance from base of internal metatarsal tubercle to tip of toe IV (FOL 29.2 mm). (21) Toes long, thin, toe IV (FTL 16.0 mm) longer than third of distance from base of tarsus to tip of toe IV (TFOL 42.4 mm). (22) Relative length of toes, shortest to longest: I < II < V – III < IV. (23) Tips of toes pointed, enlarged, with latero-ventral grooves,

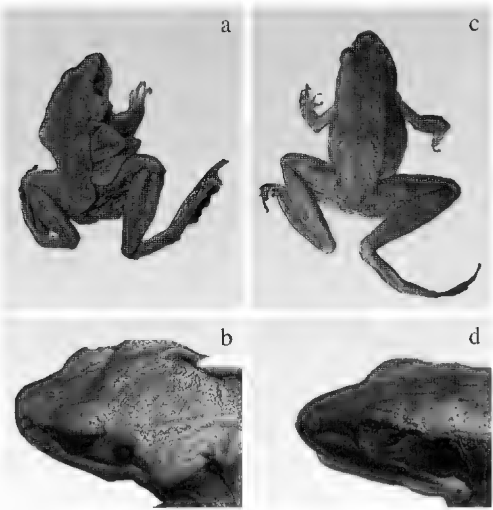

Fig. 2. – *Rana khare* (Kiyasetuo & Khare, 1986). (a) Dorsolateral view and (b) lateral view of head of an adult male KSC 107 (SVL 48.9 mm) from Jokhoma river. (c) Dorsolateral view and (d) lateral view of head of a female KSC 117 (SVL 53.3 mm), same locality.

Forelimbs. Relative length of fingers: II<IV<I<III. Tips of fingers rounded with lateroventral grooves. Subarticular tubercles prominent.

Hindlimbs. Shank (TL 26.2-32.4 mm) shorter than thigh (FL 26.3-32.5 mm) and foot (FOL 27.8-33.9 mm) in all specimens. Relative length of toes: I<II<III<V<IV. Tip of toes rounded with lateroventral grooves. Dermal fringe along toe V absent. Subarticular tubercles prominent, rounded.

Table 1. – Measurements of adult males and adult females (in millimeters). Mean values and standard deviation are given in upper line, minimum and maximum values in lower line. Measurements of males and females are statistically compared using Mann Whitney *U* test. Significance levels: * $P < 0.05$, ** $P \leq 0.01$; *** $P \leq 0.001$.

Measurement	Males *n* = 13	Females *n* = 7	*U* test
SVL	52.2 ± 4.72 (45.4-60.5)	58.3 ± 5.18 (51.6-65.2)	*U* = 19.5 *P* = 0.037 *
HW	19.2 ± 1.70 (16.0-20.9)	18.9 ± 1.75 (16.05-21.0)	*U* = 42.0 *P* = 0.817
HL	19.2 ± 1.83 (16.8-21.9)	20.8 ± 1.56 (18.4-22.7)	*U* = 21.0 *P* = 0.056
MN	15.9 ± 1.61 (12.8-18.6)	17.2 ± 1.56 (15.0-19.0)	*U* = 26.0 *P* = 0.135
MFE	11.3 ± 1.11 (9.8-13.4)	12.8 ± 1.25 (11.1-14.6)	*U* = 18.0 *P* = 0.030 *
MBE	5.79 ± 0.36 (5.4-6.8)	7.01 ± 0.91 (5.95-8.05)	*U* = 5.0 *P* = 0.000 ***
IFE	7.28 ± 1.40 (5.9-9.45)	7.6 ± 0.79 (6.3-8.8)	*U* = 34.5 *P* = 0.393
IBE	10.4 ± 1.06 (8.45-11.6)	10.3 ± 0.86 (9.5-11.8)	*U* = 35.0 *P* = 0.438
IN	6.09 ± 1.55 (4.45-10.7)	5.89 ± 0.75 (4.8-6.8)	*U* = 43.0 *P* = 0.877
EN	4.41 ± 0.73 (3.4-6.1)	4.77 ± 0.65 (4.0-5.85)	*U* = 33.0 *P* = 0.35
EL	5.84 ± 0.56 (4.8-7.05)	6.28 ± 0.67 (5.4-7.1)	*U* = 25.5 *P* = 0.115
SL	8.34 ± 0.87 (7.05-10.2)	9.06 ± 1.10 (7.55-10.6)	*U* = 28.0 *P* = 0.183
NS	4.14 ± 0.65 (3.05-4.9)	4.35 ± 0.49 (3.7-5.1)	*U* = 39.5 *P* = 0.643
TYD	2.98 ± 0.28 (2.5-3.6)	3.46 ± 0.70 (2.5-4.4)	*U* = 26.0 *P* = 0.135
TYE	1.92 ± 0.40 (1.45-2.9)	2.27 ± 0.43 (1.8-2.8)	*U* = 22.5 *P* = 0.067
IUE	4.87 ± 0.44 (4.1-5.5)	5.07 ± 0.73 (4.1-5.95)	*U* = 39.0 *P* = 0.643
UEW	5.14 ± 0.12 (5.0-5.32)	5.38 ± 0.22 (5.12-5.6)	*U* = 19.0 *P* = 0.320
FLL	12.5 ± 1.58 (9.35-14.3)	12.8 ± 1.29 (11.5-14.2)	*U* = 44.0 *P* = 0.938
HAL	12.7 ± 1.80 (9.7-15.6)	14.5 ± 1.27 (12.5-16.2)	*U* = 16.0 *P* = 0.019 *
TFL	8.00 ± 0.59 (7.25-9.15)	8.4 ± 0.71 (7.5-9.4)	*U* = 29.5 *P* = 0.211
TL	29.0 ± 2.00 (26.2-32.4)	33.2 ± 2.51 (30.4-36.5)	*U* = 6.5 *P* = 0.001 ***
FOL	30.9 ± 1.85 (27.8-33.9)	31.6 ± 1.92 (29.3-34.5)	*U* = 36.5 *P* = 0.485
FTL	18.0 ± 1.39 (16.2-20.3)	18.6 ± 1.83 (16.2-21.3)	*U* = 36.5 *P* = 0.485
IMT	2.30 ± 0.29 (1.9-2.76)	2.4 ± 0.28 (2.1-2.8)	*U* = 36.5 *P* = 0.485
ITL	5.1 ± 0.45 (4.3-6.0)	7.49 ± 1.50 (5.1-9.0)	*U* = 5.0 *P* = 0.000 ***
FL	29.8 ± 2.075 (26.3-32.5)	31.0 ± 1.98 (28.05-33.2)	*U* = 29.0 *P* = 0.211

Skin Dorsal and lateral parts of head granular. Back and upper part of flank granular with loose skin. Lower part of flank glandular with excessively developed skin forming laterally extended folded appendices. Dorsolateral folds present, prominent and narrow. Skin on dorsal forelimb granular and that of thigh granular with excessive foldings. Dorsal skin of leg granular, dorsal part of tarsus smooth. Throat and chest smooth, belly smooth with foldings. Ventral part of thigh with membranous vascularised foldings.

Coloration in life Dorsal and lateral parts of head and body slate colored. Loreal region dark grey, tympanum and tympanic region dark brown. Upper lip light grey. Lower surface of limb and body creamy white. Webbing dark brown. Extended flaps of skin slate colored without any markings.

Secondary sexual characters. – Nuptial spines granular, transparent on prepollex and finger I, forming unique pad. Vocal sacs absent. Forearm enlarged. Humeral gland on upper arm, oval, twice as long (HGL 6.5 mm) as large. Expanded membranous fold from base of humerus to groin and from vent to thigh (fig. 1a).

DESCRIPTION OF ADULT FEMALES (fig. 2c-d)

As females never have been mentioned or described, we give here a detailed description of external morphology. This description is based on seven adult females collected in amplexus in Japu stream, Jokhoma river, Rokhroma stream and Tsureng stream. Measurements are given in table 1.

Head and body - Moderate-sized frogs (SVL 51.6-65.2 mm), body elongated. Head moderate, longer (HL 18.4-22.7 mm) than wide (HW 16.1-21.0 mm) and flat above. Snout oval, protruding and longer (SL 7.55-10.6 mm) than horizontal diameter of eye (EL 5.4-7.1 mm). Canthus rostralis sharp, loreal region concave. Interorbital space flat (IUE 4.1-5.95 mm), width about equal to upper eyelid (UEW 5.12-5.6 mm) and internarial distance (IN 4.8-6.8 mm). Distance between front of eyes (IFE 6.3-8.8 mm) smaller than distance between back of eyes (IBE 9.5-11.8 mm). Nostrils round, nostrils as close to tip of snout (NS 3.7-5.1 mm) as to eye (EN 4.0-5.85 mm). Pupil rounded. Tympanum (TYD 2.5-4.4 mm) rounded. Pineal ocellus absent. Vomerine ridge present, vomerine teeth small in oblique series. Tongue large, deeply notched. Tooth-like projections on mandibles absent. Supratympanic fold prominent, from posterior region of eye to anterior part of shoulder.

Forelimbs. Forearm (FLL 11.5-14.2 mm) shorter than hand (HAL 12.5-16.2 mm), not enlarged. Relative length of fingers II<IV<I<III. Tips of fingers rounded with latero-ventral grooves; finger II with dermal fringe on inner side, webbing absent. Subarticular tubercles prominent and rounded. Prepollex oval, distinct, two oval palmar tubercles.

Hindlimbs. Shank five times longer (TL 30.4-36.5 mm) than wide, thigh (FL 28.1-33.2 mm) shorter than foot (FOL 29.3-34.5 mm), fourth toe length (FTL 16.2-21.3 mm) longer than third of distance from base of inner metatarsal tubercle to tip of toe IV (TFOL 43.5-51.0 mm). Relative length of toes I<II<III<V<IV. Tip of toes rounded, with latero-ventral grooves. Webbing present, complete. Dermal fringe along toe V absent. Subarticular tubercles prominent, rounded. Inner metatarsal tubercles distinct, oval. Tarsal fold absent. Outer

metatarsal tubercle smaller than inner metatarsal tubercle but distinct; supernumerary tubercles and tarsal tubercles absent

Skin Snout smooth, granular between eyes; side of head smooth. Posterior part of back and upper and lower part of flank granular. Dorsolateral fold prominent and narrow No lateral line or "Fejervaryan" line. Dorsal parts of forelimb, thigh, leg and tarsus smooth Ventral parts of throat, chest, belly and thigh smooth

Coloration in life – Dorsal surface of body slate to dark brown. Ventral part of body creamy white. Posterior part of thigh with dark networking

Oocytes - Large (1.8 mm diameter), animal pole pigmented light brown and vegetal pole whitish, distinctly visible through skin.

COMPARISON OF SEXES

Table 1 provides statistical comparison of measurements between series of adults of both sexes. Females have a more elongated general body shape than males. In all females, head is longer than wide, but there is no significant difference in head width between the two sexes. The head of females is significantly longer than that of males. Males have enlarged forearms. From the measurements the males are significantly smaller than females, but females have longer tibia and longer inner toe. Females also have significantly more distant eyes as measured by MFE and MBE.

These differences are rather meager compared to the morphological differentiation due to the skin flaps on lateral body and hind legs. The supratympanic folds are embedded into the lateral skin extensions in males, but form a distinct structure in females. Males have more granular skin in particular on the snout and side of the head and on the legs. Granular skin on ventral thigh is only present in males. Coloration of back and vent is quite similar in both sexes, but females can be somehow more brownish

In males, a distinct gland is present dorsally to arm insertion. There is no such gland in females. Homology to the glands present in males of other ranid groups remains to be studied In *Pterorana*, position of the gland is different from *Sylvirana*, where the gland is slightly ventral relative to insertion of upper arm, but also from *Nidirana*, where the gland is on flank posterior to arm insertion. The gland in *Pterorana* might be homologous to posterior portion of rictal gland, but enlarged.

SPAWNING BEHAVIOUR

This aquatic frog prefers swift flowing water bodies with rocky bottom and boulders or pebbles. Sometimes specimens are found in small groups of 4-5 whenever a pool is present in the swift stream

Breeding season is between October and November. Males then emit a weak call Each female lays eggs in shallow water (60-120 mm depth) with its body towards the periphery to avoid the main water current. The jelly mass contains 700-900 eggs. The clutches are attached to dead leaves, twigs or grass. The male remains near the breeding site in shallow water under the debris throughout the breeding season whereas the female leaves the place soon after laying the eggs. Parental care by the male was not observed. The extended flaps of skin of the male show high vascularisation that might help in respiration during the period the males remain in the breeding site in water.

Eggs were obtained from parents taken from the field and reared in laboratory. Each container held 15 larvae which were fed with detritus and algae. Table 2 summarizes temporal succession of development. Under laboratory condition (12-21°C water temperature), embryonic development from egg laying to hatching of larvae takes about five days. At this temperature, completion of larval cycle requires 70 days.

DESCRIPTION OF TADPOLES (fig. 3-4)

Head and body – Head and body oval (fig. 3a-b). Snout slightly rounded. Total length 25-35 mm. Nostrils rounded and open antero-dorsally. Eyes in dorsolateral position. Spiracle single and sinistral. Spiracle opening round and constricted, directed dorso-posteriorly. Vent medial. Four coils of intestine visible through skin.

Oral disc – Oral disc (fig. 3c) in subterminal position, emarginate, its width 2.0-2.3 mm. A single row of marginal papillae with a rostral gap of 0.7-0.9 mm. Upper jaw sheath entirely keratinized with lateral inflexions, serrated along entire margin, wider than lower jaw sheath, lower jaw sheath wider than deep and serrated along margin; serrations longer than wide. Figure 3d shows individual keratodont. Two rows of keratodonts on upper labium, second row interrupted by a gap of 0.4 mm and three rows of keratodonts of equal length on lower labium, inner row interrupted by a very narrow gap. KRF: 1:1+1/1+1:2.

Mouthparts. – See table 3.

Buccal floor (fig. 4a). – Buccal floor diamond-shaped, larger than long. Prelingual arena trapezoid, infralabial papillae not visible. Tongue anlage square, bearing four lingual papillae of similar size aligned on a transverse row. Buccal floor arena non-existent, no buccal floor arena papillae present, interior smooth. Buccal pockets placed very high in the buccal floor, straight and narrow, oriented almost transversally; much closer to tongue anlage than to the medial end of the ventral velum (anterior part of the left buccal pocket at the level of the tongue anlage, may be an artefact); prepocket papillae absent. Ventral velum continuous, with spicular support, its margin slightly wavy with 14 projections, one above filter plate one, two above filter plate two and height close from each other in the medial part; medial notch not evident, glottis not visible. Branchial baskets almost straight, wider than long, three gill chamber on each side; filter ruffles with tertiary folds.

Buccal roof (fig. 4b). – Prenarial arena large and oval; prenarial ridge composed of several small elements arranged in arc of a circle, few pustules dispersed within the prenarial arena. Choanae slightly oblique, oriented slightly posteromedially. Prenarial papillae slim and slightly pustulose, rising from the external half of the anterior narial wall, directed anteriorly, narial valve relatively high and smooth. Two pairs of postnarial papillae, the medial one large and pustulose, the lateral one very close to the median pair, much smaller and pointed. Medial ridge wider than high, in crescent with its free edge jagged. Lateral ridge papillae far on the

Table 2. Temporal succession of larval developmental stages in *Rana khare* under laboratory conditions. Time measured from moment of egg laying is given in hours.

Stage	Time of completion
Late blastula stage (stage 9)	12-13 h
Small yolk plug stage (stage 12)	29-31 h
Closing of neural fold (stage 15)	41-43 h
Muscular response stage (stage 18)	63-65 h
Hatching (stage 21)	112-115 h
Opercular fold (stages 24-25)	160-168 h
Hindlimb bud (stages 26-30)	380-390 h
Margin of 5th toe directed towards prehallux (stage 38)	1180-1200 h
Forelimbs emerged (stage 42)	1490-1520 h
Metamorphosis (stages 43-46)	1600-1680 h

Table 3 – Measurements (in millimeters) of a sample of 22 tadpoles (Gosner's stage 38)

Measurements	Range	Mean ± standard deviation
Total length	25-35	31 ± 3.08
Body length	7-15	11 ± 2.25
Inter-narial distance	1-3	2 ± 0.58
Inter-ocular distance	1-4	2.5 ± 0.83
Snout to spiracle	5-10	7.5 ± 1.33
Snout to nare	1-3	2 ± 0.54
Snout to eye	2-6	4 ± 1.11
Tail length	17-23	20 ± 1.65
Tail height	2-8	5 ± 1.57
Diameter of tail muscle	2-4	3 ± 0.54
Head width	2-6	4 ± 1.09
Head height	2-4	3 ± 0.59
Eye diameter	0.5-1.5	1 ± 0.29

lateral edges of the buccal roof, small, pustulose at end and oriented transversally. Buccal roof arena long, occupied by a smooth rectangular prominence, arena delimited by at least three buccal roof papillae (visible on the left side). Glandular zone wide, continues across the buccal roof. Margin and posterior part of the dorsal velum pustulose, lateral part of velum curved anteriorly, medial part of the dorsal velum not observed.

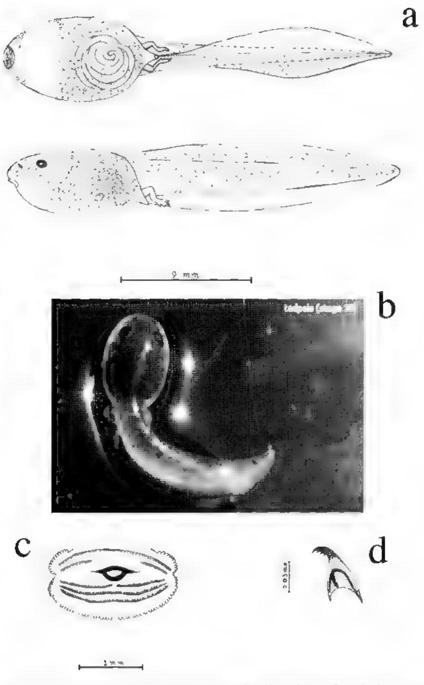

Fig 3 *Rana khare* (Kiyasetuo & Khare, 1986). (a) Ventral and lateral view of a tadpole at stage 38 (b) Alive tadpole at stage 38 (c) Oral disc of a tadpole at stage 38 (d) Keratodont

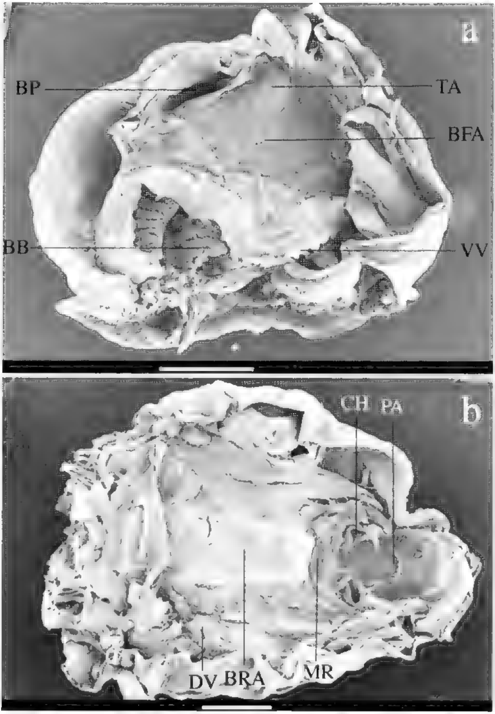

Fig. 4. *Rana khare* (Kiyasetuo & Khare, 1986). (a) Buccal floor of a tadpole at stage 38. (b) Buccal roof of a tadpole at stage 38. Scale bar, 1 mm. BB, branchial basket; BFA, buccal floor arena; BP, buccal pocket; BRA, buccal roof arena; CH, choana; DV, dorsal velum; MR, medial ridge; PA, prenarial arena; TA, tongue anlage; VV, ventral velum.

DISCUSSION

MORPHOLOGY

KIYASETUO & KHARE (1986) gave a combined description and mean measurements for the holotype and the paratype which are rather different in size (given as 53 mm for the holotype and 62 mm for the paratype). Above we provide a standard description of the holotype including its measurements. The morphological description fits quite well. We add here some details concerning structure of skin, coloration pattern and description of macroglands. Some differences (like relative length of fingers) may be due to observer interpretation for subequal values. Thus details of morphology and measurements of *Rana khare* holotype are now more largely available.

The differences observed between the holotype and the other specimens of the present study are of two origins: different observers and different observation time (e.g., differences in estimation of development of tubercles; skin structures), and different state of conservation of the specimens (e.g., shape of tips of fingers and toes). There is some variation in the studied samples of males and females in structures like head shape or proportions of hind legs. The characters of the holotype fall within the given ranges.

As sexual dimorphism is very conspicuous, the female might have been misidentified in earlier collections. The detailed description of females may help to allocate collection specimens.

Rana khare shows the morphology of a stream frog, having complete webbing and long legs (505-591 per thousands of SVL). It has morphological characters of the genus *Rana* sensu DUBOIS (1992) such as dorsolateral folds and toe pads with latero-ventral grooves. Such a morphology is consistent with the habitat indications given by KIYASETUO & KHARE (1986).

Tadpoles are characterized by a KRF basic for the epifamily Ranoidia (sensu DUBOIS, 2005) and a generalized morphology. They do not bear any character related to an adaptation to swift water, such as numerous rows of keratodonts, several rows of marginal papillae, strong caudal muscle or reduced fins (ALTIG & JOHNSTON, 1989). On the contrary, they bear typical characters of still water living tadpoles. This agrees with their microhabitat, as they are found in shallow standing water on the side of the main stream to avoid fast water current. Breeding takes place in late monsoon when the water current is slow. The structures present within the buccopharyngeal cavity are relatively reduced: on the buccal floor the infralabial papillae are absent or reduced, the prepocket and the buccal floor papillae are absent, on the buccal roof the postnarial papillae, the lateral ridge papillae, the median ridge and the buccal roof arena papillae are also reduced. The reduction of the structures is generally associated either with a strict suspension-feeding behaviour (like in the Microhylidae, WASSERSUG, 1980) or with a diet including large pieces of food (as in the genera *Hoplobatrachus* or *Amolops*; WASSERSUG, 1980; GROSJEAN et al., 2004). Torrents, the habitat of *Rana khare*, are often poor in suspensions or phytoplankton as the current carries the latter rapidly away after formation. We could assume that this species feeds on rather large particles in rasping the submerged macrophytes or the epilithic film of protists or algae, but it has no oral features associated to that diet. Nevertheless the well-developed glandular zone of the buccal roof is efficient to collect particles of all sizes and the well-developed filter ruffles must be able to collect fine particles.

Some features of the buccal cavity such as the anterior position of the buccal pockets and the prominence of the buccal roof arena are particular to this species. On the other hand, the prenarial ridge resembles that of the species of the subgenus *Rana (Sylvirana)* (Grosjean, 2004).

The data on adult and tadpole morphology lead us to review the systematic position proposed by Dubois (1992) based on adult morphological features. He placed *Pterorana* as a subgenus of *Rana* in the *Hylarana* section. As *Pterorana* have humeral glands they should be in his *Hydrophylax* subsection. It is clearly not a *Sylvirana* as it lacks the beard-like papillae on lower lip of larvae, which are an apomorphic character for *Sylvirana* + *Hylarana* (Grosjean, 2004). It is also particular by the absence of vocal sacs in males which are present in all species of *Sylvirana* and *Humerana*. The long legs and complete webbing are shared by stream living frogs, such as the species of the *Odorrana* group. In *Sylvirana*, legs are shorter in most species and webbing is never complete (Ohler, unpublished data). *Pterorana khare* shows a unique combination of characters for frogs of the genus *Rana* so it should be maintained as a subgenus of this genus. For proper allocation, study of more data, in particular molecular analysis will be needed.

Considering the proposals for ranid classification by Frost et al. (2006), it is very difficult to make decisions in their sense as no morphological diagnosis were given for the genera retained. On the presence of the fleshy folds on flanks and thigh, considered as unique in ranids (but see below), Frost et al. (2006) recognized *Pterorana* as a distinct genus. As long as there are no more data, linked to morphological studies, available on relationships in ranids, we cannot follow these conclusions.

SECONDARY SEXUAL CHARACTERS

Females of *Rana khare* exhibit a quite "normal" ranid shape with smooth skin and dorsolateral folds. Sexual characters do not only concern nuptial spines but also skin granulation and presence of dermal extensions on flanks and thighs. Like in most ranids, females are slightly larger and have longer tibia. *Rana khare* is one of the species where adult males have no vocal sac, a situation which is known in other frogs like *Polypedates mutus* (Smith, 1940) (personal observations), *Chaparana liebigii* (Günther, 1860) (Dubois, 1976) or *Limnonectes blythii* (Boulenger, 1920) (Matsui, 1995). These species emit calls and are not mute, as specific names like *mutus* would insinuate.

The presence of enlarged lateral skin in the males may be compared to similar structures observed in other ranid frogs of Eurasia some of the European brown frogs (*Rana temporaria* Linnaeus, 1758, *Rana arvalis* Nilsson, 1842) develop baggy skin during breeding season. The same can be observed in *Rana sakuraii* Matsui & Matsui, 1990 from Japan (Maeda & Matsui, 1990). Noble (1925) showed penetration of skin by cutaneus capillaries thus supporting respiratory function for such baggy skin. He also studied histology of the hairy dermal structures developed by the male of *Trichobatrachus robustus* Boulenger, 1900 during the breeding season, and found support for a similar respiratory function. In this species as in newt species with dermal respiration, reduction of lungs can be observed (NOBLE, 1925)

Both behavior (male *Rana khare* staying in the mountain streams with oxygenated water for a long period) and morphological analysis (similar parts of skin being modified) give support to the hypothesis that the "wing-like" structures are in fact additional respiratory organs. KIYASETUO & KHARE (1986) described gliding behavior in this frog. However, in species where lateral skin fringes participate in gliding behavior [e g , *Rhacophorus reinwardtii* (Schlegel, 1840)], these are not baggy and folded flaps but single layered and straight appendages. The true gliding frogs also have complete webbing on hand

In *Rana khare*, males were observed staying in the breeding site whereas females leave the breeding site soon after egg laying. Vascularised enlargement of skin might help the male in respiration while remaining in water as these hill streams provide highly oxygenated water. However, no parental care has been shown so far.

If the enlarged skin surfaces allow frogs to spent longer periods under water, they might play a role in reproductive behavior. In European brown frogs it is known that male stay longer time in breeding places than females. This presence is not due to parental care. Nevertheless the aggregation of calling males has a consequence, the aggregation of egg clutches, which increases temperature in these clutches and thus influences development of eggs. In *Trichobatrachus*, the male stays with the clutches (PERRET, 1966) and is supposed to protect them from predators (DUELLMAN & TRUEB, 1985) Thus the males stay for long periods under the water and the hairy structures of the skin will allow gas exchange in aquatic habitat

Advantages of staying under water must be different in pond frogs like *Rana temporaria* and in stream frogs like *Rana khare* or *Trichobatrachus robustus* In pond frogs it may be due to difference in temperature of water and air. *Rana temporaria* is one of the first breeders at the end of winter when temperatures of air often may fall beneath 0°C Staying in water may avoids temperature stress. But there is no such temperature problem in stream frogs occurring in tropical or subtropical regions. The main problem for these frogs might be the current of the streams. Staying in the profound parts of the water body limits the energy necessary to counterpart the flow as its speed is diminishing when approaching the bottom of stream. Both vascularized dermal appendages for respiration and diminished gas volume in lungs of *Trichobatrachus* can be adaptations to staying for a long time under water. If frogs choose breeding places or have territorial behavior, it is important for reproductive success to be able to stay in these places. By avoiding to go through regularly strong currents and to be washed away from favorable breeding places, they enhance their fitness. Further studies of internal anatomy and histology are needed confirm our hypothesis on function of skin flaps in *Rana khare*.

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Literature cited

Altig, R. & Johnston, G. F., 1989. Guilds of Anuran larvae. Relationships among developmental modes, morphologies, and habitats. *Herpetological Monographs*, **3**: 81-109.

Altig, R. & McDiarmid, R. W., 1999. – Body plan. Development and morphology. *In*: R. W. McDiarmid & R. Altig (eds.), *Tadpoles. The biology of anuran larvae*, Chicago and London, The University of Chicago Press: 24-51.

Ao, J. M., Bordoloi, S. & Ohler, A., 2003. Amphibian Fauna of Nagaland with nineteen new records from the state including five new records for India. *Zoo's Print Journal*, **18** (6): 117-125.

Chanda, S. K., 1994. Anuran (Amphibia) fauna of North East India. *Mem. Zool. Surv. India*, **18** (2): 1-143.

Chanda, S. K., Das, I. & Dubois, A., 2000. Catalogue of Amphibian types in the collection of the Zoological Survey of India. *Hamadryad*, **25** (2): 100-128.

Dey, M. & Ramanujam, S. N., 2003. Record of *Pterorana khare* Kiyasetuo and Khare, 1986 (Anura: Ranidae) from Aizwal District, Mizoram, North Eastern India. *Hamadryad*, **27** (2): 255-256.

Dubois, A., 1976. Les Grenouilles du sous-genre *Paa* du Nepal (famille Ranidae, genre *Rana*). *Cahiers népalais. Documents*, Paris, CNRS, **6**: i-vi + 1-275.

----- 1992. Notes sur la classification des Ranidae (Amphibiens, Anoures). *Bull. Soc. linn. Lyon*, **61** (10): 305-352.

----- 1995. Keratodont formulae in anuran tadpoles: proposals for a standardization. *J. Zool. Evol. Research*, **33**: i-xv.

----- 2005. *Amphibia Mundi*. 1.1. An ergotaxonomy of recent amphibians. *Alytes*, **22** (1-2): 1-24.

Dubois, A. & Ohler, A., 2000. Systematics of *Fejervarya limnocharis* (Gravenhorst, 1829) (Amphibia, Anura, Ranidae) and related species. 1. Nomenclatural status and type-specimens of the nominal species *Rana limnocharis* Gravenhorst, 1829. *Alytes*, **18**: 15-50.

Duellman, W. E. & Trueb, L., 1985. *Biology of amphibians*. New York, McGraw-Hill, "1986": i-xix + 1-670.

Frost, D. R., Grant, T., Faivovich, J., Bain, R. H., Haas, A., Haddad, C. F. B., De Sa, R. O., Channing, A., Wilkinson, M., Donnellan, S. C., Raxworthy, C. J., Campbell, J. A., Blotto, B. L., Moler, P., Drewes, R. C., Nussbaum, R. A., Lynch, J. D., Green, D. M. & Wheeler, W. C., 2006. – The amphibian tree of life. *Bull. Amer. Mus. Nat. Hist.*, **297**: 1-291.

Gosner, K. L., 1960. A simplified table for staging anuran embryos and larvae with notes on identification. *Herpetologica*, **16**: 183-190.

Grosjean, S., 2004. *Apport des caracteres larvaires à la phylogenie des Amphibiens Anoures. Cas de deux familles: les Megophryidae et les Ranidae*. These du Museum National d'Histoire Naturelle, Paris: i-iv + 1-177 + [i-xxiv] + 1-261 + [i-cx] + 101 pl.

----- 2006. The choice of external morphological characters and developmental stages for tadpole-based anuran taxonomy: a case study in *Rana (Sylvirana) nigrovittata* (Blyth, 1855) (Amphibia, Anura, Ranidae). *Contrib. Zool.*, **74** (1-2): 61-76.

Grosjean, S., Vences, M. & Dubois, A., 2004. Evolutionary significance of oral morphology in the carnivorous tadpoles of tiger frogs, genus *Hoplobatrachus* (Ranidae). *Biol. J. linn. Soc.*, **81** (2): 171-181.

Kiyasetuo & Khare, M. K., 1986. A new genus of frog (Anura: Ranidae) from Nagaland at the north-eastern hills of India. *Asian J. Expl. Sci.*, **1**: 12-17.

Maeda, N. & Matsui, M., 1990. *Frogs and toads of Japan*. Second edition. Tokyo, Bun-Ichi Sogo Shuppan Co. Ltd.: i + 1-206 + i.

Matsui, M., 1995. Calls produced by a "voiceless" frog, *Rana blythii* Boulenger 1920 from Peninsular Malaysia (Amphibia: Anura). *Tropical Zool.*, **8**: 325-331.

Noble, G. K., 1925. The integumentary, pulmonary, and cardiac modifications correlated with increased cutaneous respiration in the Amphibia: a solution of the "hairy frog" problem. *J. Morph. Physiol.*, **40**: 341-416.

Ohler, A., 1996. Systematics, morphometrics and biogeography of the genus *Aubria* (Ranidae, Pyxicephalinae). *Alytes*, **13**: 141-166.

OHLER, A., SWAN, S. R. & DALTRY, J. C., 2002. A recent survey of the amphibian fauna of the Cardamom mountains, southwest Cambodia with descriptions of three new species. *Raffles Bull. Zool.*, **50** (2), 465-482.

PERRET, J.-L., 1966. Les Amphibiens du Cameroun. *Zool. Jahrb., Syst., Ökol. Geogr. Tiere*, **93**: 289-464.

POWER, S. & BIRAND, A. 2001. Survey of Amphibians, Reptiles and Birds of North East India. *CERC Tech. Report*, **6**: 1-118.

SEN, N. & MATHEW, R., 2003. Range extension of *Pterorana khare*,1986 (Anura: Ranidae) with notes on some morphological characters. *Cobra*, **53**: 5-8.

WASSERSUG, R. J., 1976. Oral morphology of anuran larvae: terminology and general description. *Occas. Pap. Mus. Nat. Hist. Univ. Kansas*, **48**: 1-23.

--- 1980. - Internal oral features of larvae from eight anuran families: functional, systematic, evolutionary and ecological considerations. *Misc. Publ. Mus. Nat. Hist. Univ. Kansas*, **68**: 1-146.

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